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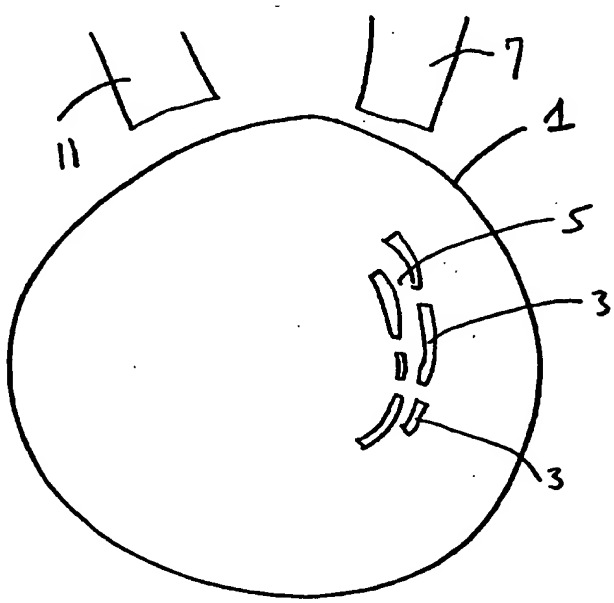
(54) Title: DUAL DATA RECORDED COMPACT DISC



(57) Abstract

The optical recording device including a reading head (11) and a reading laser (7) for encoding optical data (3) on a CD (1) as two dimensional (i.e. pit length and pit depths (13, 15)) optical data (3) along a spiral track, one of the data streams may be used to implement a hologram on the data recording surface, the preferred form of the invention uses a uniform pit depth within each pit, causing pit depth to vary only from pit to pit and not within a single pit, the second data stream relies on the primary data stream for much of the necessary error correction required in dense data transmission media.

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DUAL DATA RECORDED COMPACT DISC

BACKGROUND OF THE INVENTION

Compact discs are typically composite objects having a series of pits impressed into a plastic surface, usually during an injection molding process. These pits and the lands between them are arranged in a spiral pattern that can be tracked by a laser beam which advances slowly along a radius while the disc is spun about an axis through the center of the disc. The pit/land surface is coated with a thin reflective metal layer. The laser beam is reflected from the metal layer coating the pits and lands and the reflection is analyzed to observe the change in reflectivity associated with a transition from a land to a pit or vice versa. To enhance the change in reflectivity the wavelength of light is chosen to cause interference between light reflected from the bottom of a pit and light reflected from a land. In common practice, the light is incident from the side that sees the pit as a bump, and the reference to light reflected from the bottom of a pit herein may be understood as light reflected from the pit seen from beneath as a bump.

The wavelength of light is not chosen arbitrarily, but is related to the depth of the pits. By detecting the change in reflectivity, the length of the pit and or land is measured. Data is encoded onto the compact disc as varying lengths of the pits and lands. The data may be analog or digital data. For example a voltage level may correspond directly to a pit length in an analog recording, or the length of the pits/lands

may represent strings of 0's or 1's for the recording of digital data.

The amount of data that can be encoded onto a disc is limited by the density of pits and lands that can be accurately reproduced by the injection molding procedure and that can be accurately read by the scanning laser device. Some error rate can be tolerated if the data is placed on the disc in a somewhat redundant format that allows errors to be sensed and corrected. Thus as the pits and lands are decreased in size it becomes necessary to provide greater redundancy in the data until a limit is reached in the amount of data that can be stored on the disc surface.

BRIEF DESCRIPTION OF THE INVENTION

The present invention stores two separate streams of optical data on a CD as two dimensional (i.e. pit length and pit depth) data along the spiral track. One of the data streams corresponds to pit depth and may be used to implement a hologram on the data recording surface. The preferred form of the invention uses a uniform pit depth within each pit, causing pit depth to vary only from pit to pit and not within a single pit. The second data stream requires less error correction data encoded as pit depth; it relies on the primary data stream encoded as pit length for much of the necessary error correction required in the compact disc.

The invention also comprises a novel method for manufacturing such a two dimensionally encoded compact disc and a

novel method for reading the data using level detectors to separate the two data streams.

The invention relies on the unexpected discovery that it is not necessary to fix pit depth at one quarter of a wavelength of the reading laser in order to effectively read data from a compact disc.

An alternative embodiment of the present invention does not record a separate secondary data bit in each pit/bump but rather uses a clock to record a bit in each equal time interval corresponding to at least the largest time interval occupied by a pit/bump under the reading head. In that case one of the level detectors used to read the data is replaced by a clock. This records less data than the preferred embodiment, but has the advantage of simplifying the system electronics.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 represents a schematic view of a CD and its reading components.

Fig. 2 represents a cross section view of the data recording surface of a CD according to the present invention.

Fig. 3 represents the intensity level diagram for the output voltage signal at the reader head of a CD player for the present invention.

Fig. 4 represents a schematic block diagram of the algorithmic logic of the data interpreter of the present invention.

Fig. 5 represents a diagram of the intensity level for

the output voltage signal showing the voltage levels triggering the logic of Fig. 4.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

The present invention implements an unexpected discovery concerning data recorded as pits on a compact disc, namely that the depth of the pits is, contrary to the published literature, not a critical parameter in the manufacture of such discs. For purposes of this disclosure the compact discs will be referred to as CDs, but it should be understood that the term CD is intended to include multiple sided compact discs and to the DVD format or other optical recording formats as well.

In particular, it has been unexpectedly discovered that a laser reading beam need not have a wavelength that is approximately 4 times the depth of a pit or bump. Indeed it has been unexpectedly discovered that a wavelength approximately 2 times the depth of a pit or bump is most effective for reading data from the compact disc. This directly contradicts the simplistic view of the interference/diffraction/scattering effects at the surface of the data region of a compact disc and is believed to be caused by the complexity of the interference/diffraction of light from an irregularly pitted surface.

This unexpected discovery opens up literally a new dimension for the storage of digital data on compact discs. Whereas data has been stored one dimensionally as pit lengths along

a spiral track, the present invention enables one to store the data two dimensionally as both pit length and pit depth along the spiral track. The preferred embodiment of this invention uses a uniform pit depth for each pit, causing pit depth to vary only from pit to pit and not within a single pit. This provides two advantages. First it enhances quality control because it is possible to recognize unintended pit variation when it occurs within a single pit. Second it enables the use of conventional data recording equipment in the compact disc recording field.

Figure 1 depicts a compact disc 1 or single surface of a two sided disc with the data pits 3 greatly enlarged. The pits are arranged in a spiral pattern with a land area 5 between adjacent spirals so that they may be read in sequence by a reading laser 7. Figure 2 depicts a cross section of the information bearing surface 9 of the compact disc, preferably a metallic film capable of reflecting laser light, the film being embedded in a plastic protective layer through which laser light reflected from the data surface may be detected by a reading head 11. The surfaces are formed with pits of varying depth, by a method to be described below, and the reading head contains a peak detecting means that is capable of sensing the depth of pit.

Figure 3 shows a typical voltage signal as a function of time corresponding to the intensity of the light received in the photodetector of the reading head of the compact disc player. Since the disc rotates at constant linear velocity

under the reading head Figure 3 also shows an indication of the depth of the pit along the data track. As shown in Figure 3, a low intensity signal 13 represents a pit having a wavelength of approximately $\lambda/2$. A medium intensity signal 15 represents a pit having a wavelength of approximately $\lambda/4$. A high intensity signal 17 represents a land area between pits on the data recording surface.

In operation the reading head of the player senses a variation of intensity of the signal reflected from the data containing surface. The intensity encodes two data signals that must be unfolded from each other. This is accomplished by the algorithm schematically represented in Fig. 4. The signal is first passed through a signal splitter and one portion is sent to a logical analyzer 21 to perform the normal CD interpretation of the pit/bump length data. The second portion is sent to logical analyzer 23, i.e., a level detector which recognizes the crossover from the land to a pit bump (see point 25 in Fig.5). The level detector 23 then enables the AND gate 27 and passes the signal to a high level detector which causes the AND to go high only if the pit/bump depth is sufficiently deep. In the preferred embodiment each pit presents the opportunity to encode a single secondary data bit regardless of the length of the pit/bump. The logic presented recognizes the termination of a single pit/bump in order to provide for the situation where two identical bits occur in succession.

An alternative embodiment of the present invention does

not record a separate secondary data bit in each pit/bump but rather uses a clock to record a bit in each equal time interval corresponding to the largest time interval occupied by a pit/bump under the reading head. In that case the first level detector is simply replaced by a clock. This has the disadvantage of recording less data, but the advantage of simplifying the system by eliminating the need to continuously locate the edge of a pit/bump.

One advantage of the present invention is that it is not necessary to provide error correction in as much detail for the secondary data as for the primary data, because the primary data can contain such information as is necessary to locate the origin of a data word in the event that foreign particles obscure the data. In effect, checksum data or its equivalent which is provided in the primary data will show when reading errors have become excessive and the reading head can assume that such errors are not affecting the secondary data if they have not affected the primary data. This piggyback effect, is not to my knowledge implemented in any other form of data communication.

The process for manufacturing a disc according the present invention is as follows:

The normal manufacturing process for a CD is altered by taking the normal laser writing signal that is modulated in an on/off manner to encode the pits and further modulating the intensity of the laser to create different exposure levels in the photoresist or in the non-photoresist coating on a glass

master. In an ablative process the same variation in laser intensity is performed. Typical wavelengths for the reading light are 780 nm for CD's and 650 nm for DVD's.

One use for the present invention is to superpose a hologram onto the data portion of the data recording surface of a CD. This is accomplished by taking a conventional hologram from a surface where one is impressed in plastic and recording the height of each pixel element and expressing that data in a digital form for recording on the surface of a CD. This causes a slight distortion of the hologram since the present invention is restricted to pixels that correspond in dimension to the length of the available pits. It has unexpectedly been discovered, however, that in view of the small size of the pits/bumps on the surface a conventional hologram, that this slight distortion is not a significant detriment to the operation of this method. This effect is minimized in the embodiment where a clock is used to define the pixel size rather than relying on the individual pit/bump length.

WHAT IS CLAIMED IS:

1. A disc medium for the optical recording first and second digital data for readout by a laser having a wavelength λ comprising

a series of pits arranged in a spiral pattern in a reflective material having

a predetermined plurality of lengths encoding first digital data and

a separate predetermined plurality of pit depths encoding second digital data,

wherein said plurality of pit depths comprises at least the depths $\lambda/2$ and $\lambda/4$.

2. The disc medium for optical recording of claim 1 wherein said second digital data comprises a bit pattern which when implemented in variable pit depths forms a hologram observable through a transparent surface of said disc medium.

3. The disc medium for optical recording of claim 1 wherein said second digital data comprises a bit pattern which when implemented in variable pit depths forms a security encoded area on said disc.

4. The disc medium for the optical recording of claim 1 wherein the second digital data is encoded by a pit of greater depth ($\lambda/2$) representing a digital 1 and a pit of lesser depth ($\lambda/4$) representing a digital 0 or vice versa.

5. The disc medium for the optical recording of claim 1 wherein the second digital is encoded by a transition from a pit of greater depth ($\lambda/2$) to a pit of lesser depth ($\lambda/4$)

representing a digital 1 and the absence of such a transition representing a digital 0, or vice versa.

6. The disc medium for the optical recording of claim 1 wherein said pit depths include n-2 additional depths and each such pit depth represents a digit in a base n system, wherein the density of data represented by said pit depths is enhanced by a factor of $(n/2)^x$ where x is the word length.

7. A system for reading dual digital data from a compact disc having data pits with variable length and variable pit depth comprising

peak detector means for detecting the depth of a pit.

8. A method for separating two data signals from a CD having variable pit/bump length and pit/bump depth, comprising

sensing a variation of intensity of a signal reflected from a data containing surface, wherein the intensity encodes two data signals, that must be unfolded from each other,

splitting the signal and sending one portion to a logical analyzer,

performing the normal CD interpretation of the pit/bump length data,

sending a second portion of the signal to a second logical analyzer comprising a level detector,

recognizing the crossover from the land to a pit bump

implementing logical circuitry to determine whether the pit/bump depth is sufficiently deep.

9. A method for separating two data signals from a CD having variable pit/bump length and pit/bump depth, comprising

sensing a variation of intensity of a signal reflected from a data containing surface, wherein the intensity encodes two data signals, that must be unfolded from each other,

splitting the signal and sending one portion to a logical analyzer,

performing the normal CD interpretation of the pit/bump length data,

sending a second portion of the signal to a second logical analyzer comprising a level detector,

clocking a signal to indicate the start of a new depth encoded data bit,

implementing logical circuitry to determine whether the pit/bump depth is sufficiently deep.

10. A disc medium for the optical recording first and second digital data for readout by a laser having a wavelength λ comprising

a series of pits arranged in a spiral pattern in a reflective material having

a predetermined plurality of lengths encoding first digital data and

a separate predetermined plurality of pit depths encoding second digital data,

wherein said plurality of pit depths comprises at least two different predetermined pit depths.

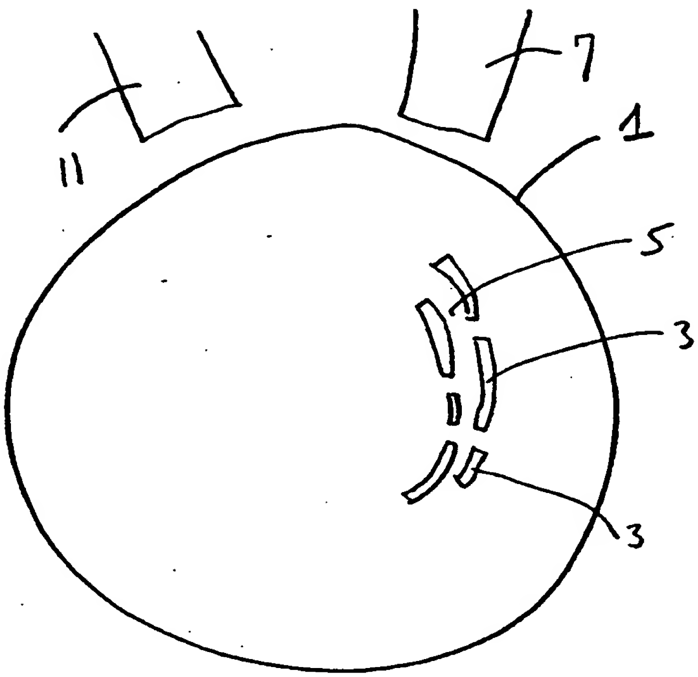

Fig 1

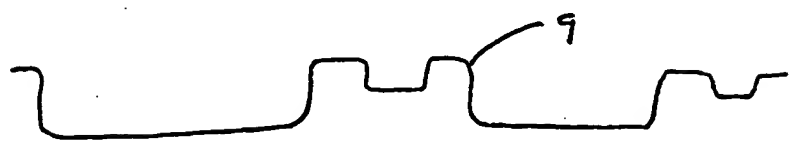

Fig. 2

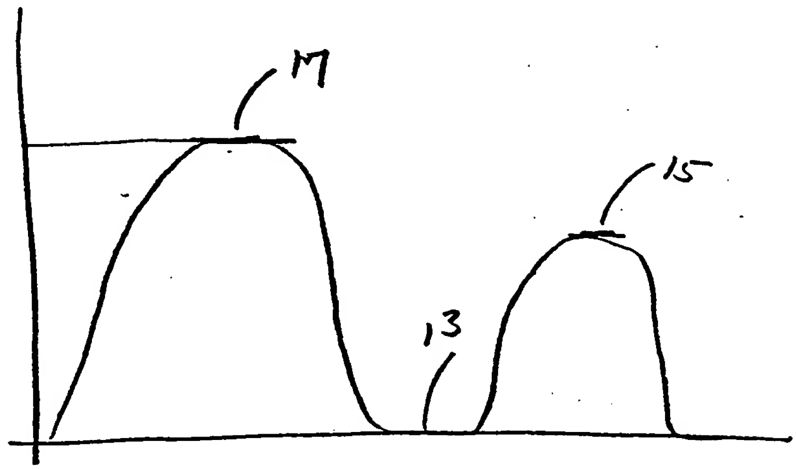
M
15
13

Fig 3

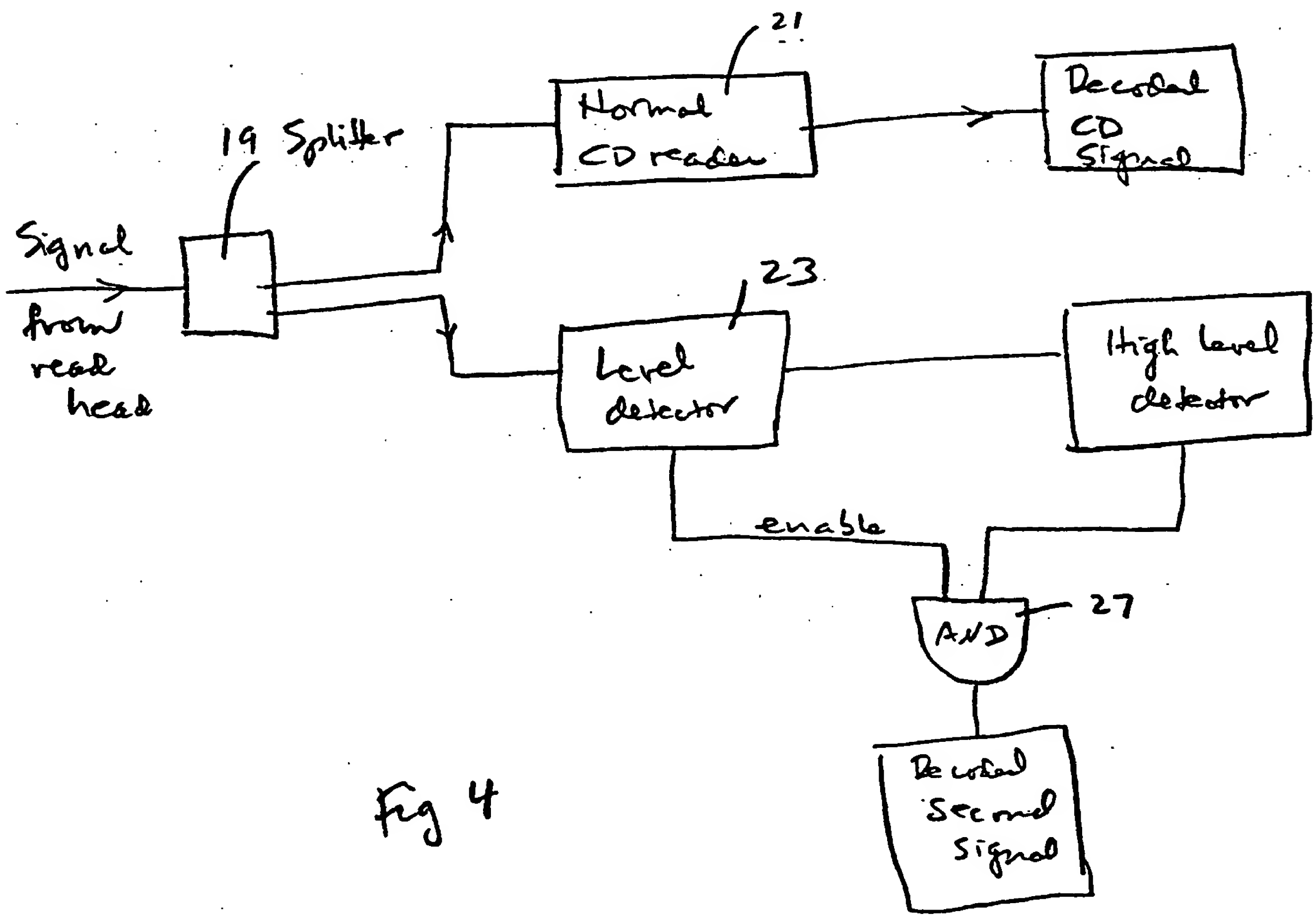
21
Normal CD reader
Decoded CD Signal
19 Splitter
Signal from read head
23
Level detector
High level detector
enable
AND
27
Decoded Second Signal

Fig 4

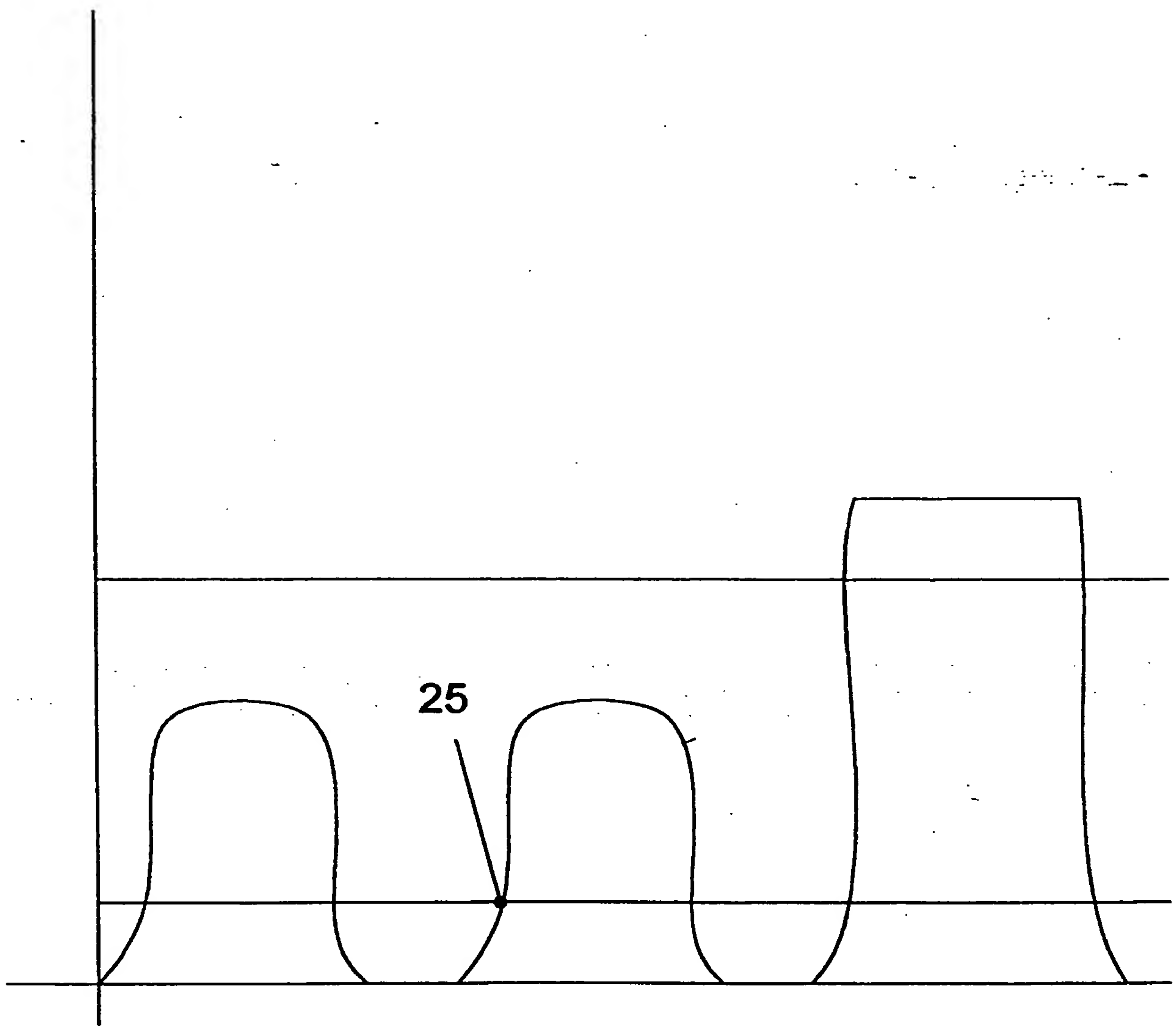

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :G11B 7/24
US CL :369/275.4, 275.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 369/275.4, 275.1, 275.3, 109, 103

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
A.P.S

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,577,016 A (INAGAKI et al) 19 November 1996 (19-11-96), figure 1; column 16, lines 10-56; column 18, lines 56-61.	1-5,10
X	US 5,559,787 A (NOMOTO) 24 September 1996 (24-09-96), figure 4A; column 3, line 22 to column 4, line 51; column 5, lines 25-52.	1-5,10
A	US 5,471,455 A (JABR) 28 November 1995 (28-11-95), whole document.	None
A	US 5,453,969 A (PSALTIS et al) 26 September 1995 (26-09-95), whole document.	None

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
14 OCTOBER 1997

Date of mailing of the international search report
24 OCT 1997

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-6,10

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid. The groups are as follows:

Group I, claim(s) *1-6 and 10*, drawn to an optical disk.
Group II, claim(s) *7*, drawn to peak detector.
Group III, claim(s) *8 and 9*, drawn to a method for separating two data signals from a CD.

The inventions listed as Groups I,II and III do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The claims of groups I,II and III are differed in structures/arrangement/combinations during storing information data, for example, the invention of group I is directed to an optical recording medium in general for storing information data, the invention of group II is directed to a peak detector circuit for detecting the depth of the recorded pits, and the invention of group III is seem usefull for separating two data signals from a CD.